Abstract No. ragh0498

Synchrotron X-ray Characterization of Ammonothermal Grown GaN Crystals

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Beamline(s): X19C

Introduction: Wide band gap nitride semiconductors are promising materials for a broad range of electronic and opto-electronic devices such as electronic devices capable of operation at elevated temperatures, high power or high frequency, and short-wavelength optoelectronic devices such as solar blind UV light detectors, blue LEDs or UV laser diodes. Currently, some of these applications are being realized by growing heteroepitaxial device structures on SiC or sapphire substrates, but lattice mismatch and incompatibility issues limit their performance. A homoepitaxial relationship between device and substrate should drastically lower dislocation density in the epilayers and thus greatly improve the performance and lifetime of the devices. For this, there is a requirement for large area, low defect density, single crystal AlN or GaN substrates. Quality of GaN crystals synthesized by the ammonothermal method is evaluated here.

Methods and Materials: GaN crystals were synthesized by the ammonothermal method using potassium azide (KN_3) as mineralizer and GaN (powder and/or crystals) as feedstock [1]. X-ray diffraction patterns from GaN crystals were recorded at the Stony Brook Synchrotron Topography Station, Beamline X19C.

Results: GaN crystals grown showed two types of crystal morphology - platelets parallel to (0001) and prismatic, needle-shaped crystals whose long axis was the [0001] direction. To verify the 2H crystal structure of GaN is that synthesized by the ammonothermal method, transmission Laue diffraction patterns obtained from the crystals with the synchrotron white beam were compared with computer-generated Laue diffraction patterns using standard 2H–GaN crystal structure data. Fig.1(a) shows juxtaposed experimental and simulated patterns for an x-ray beam perpendicular to the $(10\bar{1}0)$ face of a prismatic crystal, and Fig. 1(b) patterns for the beam perpendicular to the (0001) face of a platelet. Comparison reveals excellent matches, thereby verifying that the ammonothermal GaN crystals were of 2H crystal structure type. Diffraction spots formed by the [0001] prismatic needles were relatively well defined, as in Fig. 1(a), while the diffraction spots obtained from the (0001) platelets showed varying amounts of streaking, as in Fig. 1(b). The streaking is due to mosaicity, a condition of strain and subgrain structure consisting of low-angle tilt boundaries. Prismatic needles are characterized by a low degree of mosaicity, less than 10 arcmin, while basal plane platelets show higher mosaicities, from 20–300 arcmin. X-ray topographs recorded from crystals of low mosaicity of both morphologies are shown in Fig. 2. The overall defect densities of the platelets are 10^6 cm^{-2} or higher.

Conclusions: Synthesis of 2H GaN crystals by the ammonothermal method was verified. Two types of crystal morphologies were observed: prismatic needles of relatively good crystalline quality, and basal plane platelets with a wide range of mosaicities.

Acknowledgments: Work supported by ONR via North Carolina State U. as part of the MURI on ‘‘Growth and Wafering of Bulk III-Nitrides’’ (Contract Monitor Dr. Colin Wood) and under contract N00014-01-1-0302 (Contract Monitor Dr. Colin Wood). Topography was carried out at the Stony Brook Synchrotron Topography Facility, beamline X-19C, at the NSLS, BNL, which is supported by DOE under Contract No. DE-AC02-76CH00016.

References:

[1] D.R. Ketchum, J.W. Kolis, J. Crystal Growth **222**, *431* (2001).

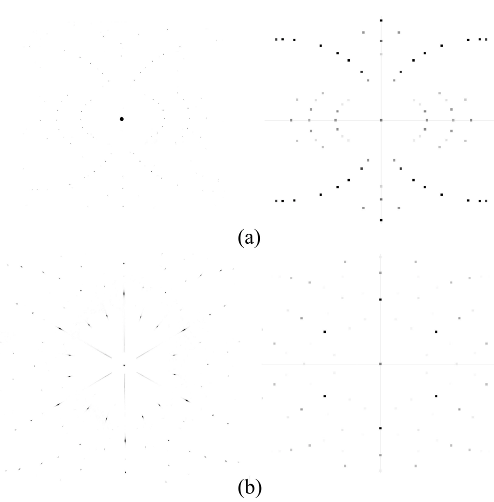

Fig.1. (a) Experimentally recorded & computer simulated Laue diffraction patterns from (a) $(10\bar{1}0)$ face of a 2H-GaN prismatic needle, and (b) (0001) face of a 2H-GaN platelet.

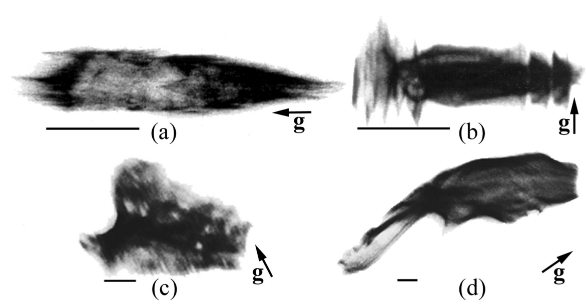

Fig.2. (a)Transmission x-ray topographs of GaN crystals: Prismatic needles (a) g = 0002 & (b) g = $11\bar{2}0$; Basal plane platelets (c) g = $\bar{4}222$ & (d) g = $4\bar{2}\bar{2}2$. Scale: 200μm.